Open innovation in project-based industries

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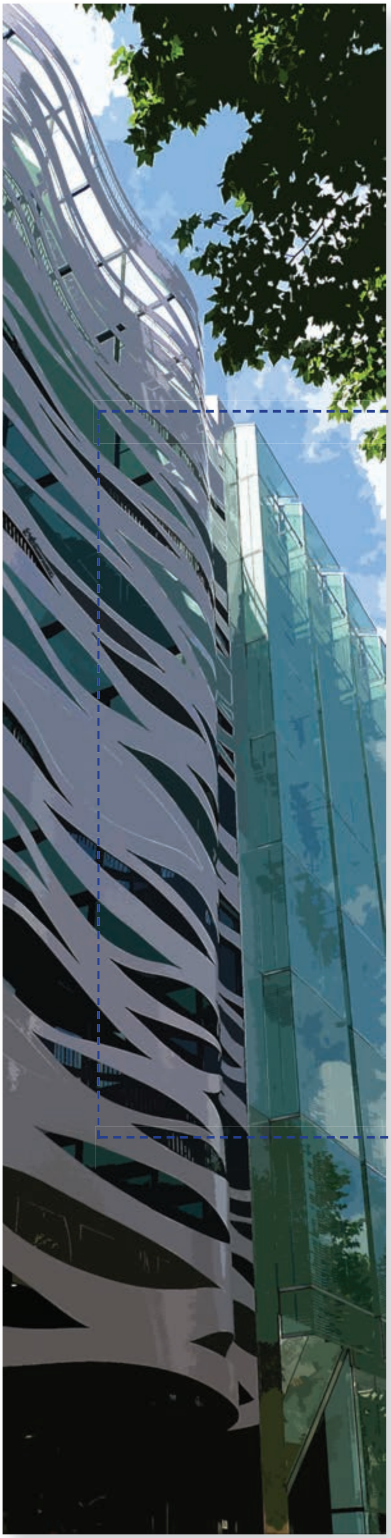

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OPEN INNOVATION IN PROJECT-BASED INDUSTRIES: THE CASE OF AN OPEN INNOVATION PROJECT IN CONSTRUCTION

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Based on the theoretical approach of open innovation and an exemplary case study of an open innovation project, this paper explores the conditions and opportunities for open innovation in the construction sector with a special focus on the importance of the context for both process and outcome. The concept of open innovation is explored theoretically and empirically in many different industries as a new perspective for understanding the companies' needs and ability to optimise and adapt their innovation processes to new market conditions. The construction sector is a particularly relevant example to learn from, since the construction context is characterised by cooperation between many actors, where design, planning and execution are carried out by project-based businesses, while deliveries of building components and materials are carried out by manufacturing companies. The two central actors in the innovation project in question were a major Danish architectural firm and a major building component manufacturer. The aim of the project was two-fold: to develop a concept for open innovation in construction and to develop daylight and energy solutions for the construction sector. The project was followed from June 2009 to November 2011 and methods used in the data collection were participant observation, documentary material and interviews. Experience showed that specific configurations of open innovation can be difficult to plan when a specific configuration of open innovation is developed and stabilised together with a concrete innovation prototype, which means that the innovation concept and the innovation prototype as artefact, knowledge, methods etc. is result of the same process.

KEYWORDS: Open innovation, daylight, energy, construction industry

1 INTRODUCTION

In Denmark, the energy performance of buildings has long been in focus, initially prompted by the energy crises in the 1970s and today based on environmental and climate debate. Improving the energy performance of buildings is perceived as a central part of the solution to climate change and the construction industry plays an important role in the transformation process. Energy strategies as reflected in the Danish Building Regulations have changed character and overall, one can describe the evolution as a shift from a prescriptive regulation to performance-based regulation. Regulation affects individual companies and overall innovation of the delivery system, which is obvious, since regulation is part of the institutional context in which companies operate. With the change in the Danish Building Regulations from a descriptive regulation to an energy-performance-based regulation, energy became a new design theme in the construction industry or more precisely the design practice around heating, cooling, daylight etc. were put under pressure and opened up for new interpretations.

Buildings are generated by integrating many products and services that together form a complex product system, where a large number of independent companies have to operate in networks with complex interfaces (Gann and Salter, 2000). Unlike traditional industry, the dominant mode of production in construction is project based, where design, planning and execution are carried out by project-based businesses, while deliveries of building components and materials are carried out by manufacturing companies. As a consequence, the construction sector is often defined by its project-based nature, and innovation in the construction sector is usually to be understood on the project's premises. This has resulted in a situation where the analytical focus often has been on how the project-based businesses can require demands directed upstream in the supply system as part of an innovation process (Forman et al., 2012). It is well known that the new energy requirements for construction has led to the energy performance of new buildings becoming thematised earlier in a building's design process, which in turn often leads to increased interaction on energy already in the design phase between architects and engineers from project-based companies. The boundaries between building component manufacturers and project-based companies are more blurred. In this paper, we aim to understand the dynamic of innovative processes that are initiated and shaped by a component manufacturer and a project-based company.

Theoretically, we build on the strands of technology-oriented research within open innovation studies as well as science and technology studies (STS). Open innovation relates to innovation processes at companies, where companies open up towards - and involve - the surroundings in their innovation processes and free revealing of product and process designs. Core concepts in this strand of research are different configurations of open innovation (Enkel et al. 2009 Gassmann, 2006), innovation incentives that support free revealing (von Hippel and von Krogh, 2006) and how innovation technologies influence open innovation (Dodgson et al. 2006). The concepts seem fruitful in our case, because the interaction aspect between the companies is central to the development of new energy solutions. In STS, the social shaping of technology approach relates to technological development and change as socially shaped and designed, and attention is given to the innovative agency of actors in the dynamics of technology development. Core concepts are relevant social groups, problems and solutions, technological frames and interpretative flexibility (Bijker1992, 1995).

The case study of this paper is based on an analysis of an open innovation project for new energy and daylight solutions in the construction industry and aims to develop a better understanding of open innovation in the construction industry between building component manufacturers and project-based companies. The paper is structured in four major parts. The next section outlines our theoretical position within the concerns of both open innovation studies and STS. Then a description of the methodology follows, which includes a description of the societal conditions that made it possible to create the project. Next, we offer an empirical analysis. The first part is a description of the involved companies and the second part addresses the processes of developing and stabilisation of three new solutions for energy and daylight building components (suggestions) in the interaction between the project-based company and the building component manufacturer. We explore roles, interests, skills and agreements that are in play in the social shaping process and their impact on future energy and daylight structures in the construction sector. Finally, we discuss our empirical findings related to current experience gained from open innovation studies.

2 THEORETICAL FRAMEWORK

In the design of our theoretical framework, we draw on two fields of research that address the various relations between actors in developing new products/technologies. Both open innovation studies and STS elaborate the relation between actors theoretically and empirically. The two research approaches pursue divergent objectives, as reflected in divergent research agendas. The open innovation approach is primarily business oriented and aims to enhance the quality of a company's innovation process by making companies aware of external actors as a potential rich source of innovative ideas for product development (Enkel et al. 2009; Gassmann, 2006) and how free revealing can make good sense (von Hippel and von Krogh, 2006). The social shaping of technology approach is primarily a critical and alternative perspective of the perception of technological development as deterministic and aims to enhance the understanding of technology development as a social process by showing how technical objects and social relations are bonded together and how actors and technology are co-produced (Bijker 1982, 1995). In the next paragraph, we discuss how the two fields conceptualised innovative structures and the dynamic of innovation structures

Open innovation processes involve both flows going outside and into the company and vice versa. Based on a process perspective, Enkel et al. (2009) point to three key processes that can be separated in open innovation: 1)*'The outside-in process'* which is about how companies can enrich / increase their knowledge base through the integration of knowledge from suppliers, customers and other external sources of knowledge. In these processes, there is increasing awareness of the importance of innovation networks etc. 2) '*The inside-out process*' is about the ability of companies to increase their profits by bringing their ideas to market through external actors. This may be situations where it can be faster than the internal development of the companies. Within these processes there is an increased attention to new business models such as new types of companies using IP (intellectual property rights), new forms of licensing and commercialisation of their own technologies in emerging markets. 3*) 'The coupled process'* refers to the co-creation between mainly complementary partners through alliances, cooperation or joint venture in which the "give and take" is central to success. Within these processes, there has been special focus on open source projects, consumers, lead users, universities and research organisations and partners from other industries.

Von Hippel and von Krogh (2006) strengthen the definition of open innovation by highlighting free revealing of products and process designs as a defining characteristic of open innovation. They introduce three models of innovation incentives: 1) The Private Investment Model, where the assumption is that 'Innovators will gain higher profits than free riders only if innovations are not freely revealed as public goods' (p 303), 2) the Collective Action Model, where the assumption is that 'Innovators and free riders profit equally from innovations contributed as public goods' (p 303), and 3) the Private-collective Model, where the assumption is that 'Innovators gain higher profits than free riders from freely-revealed innovations because some sources of profit remain private' (p 303). They argue that the Private-collective model exists as an alternative to the other two models, and is possible because the innovators despite free revealing of innovations get private benefits such as learning, enjoyment and affiliation to teams, communities etc. They argue that the Private-collective model offers the best to society as 'new knowledge is created by private funding and then freely offered to all' (von Hippel and von Krogh, 2006, p. 304).

Dodgson et al. (2006) suggest that companies' shift to open innovation is associated with greater organisational and technological change and focus in their case study of "Procter & Gambler" on the importance of innovation technologies for development towards open innovation. Besides the ICT, innovation technologies are a number of new technologies such as simulation, modelling, virtual reality, data mining and rapid prototyping technologies. They show how the use of the new innovation technology recreates the way a company manages its innovation processes and identifies the following relations: 1) The increased external search activities have required cultural change in the organisation and it has taken place over a long period. Changes have been towards a more decentralised R&D structure. Furthermore, the use of innovative technology has demanded new skills. 2) The technology does not replace existing practice, but can optimise it. Innovation technology can for example result in that physical prototypes will being developed later, when there are fewer unknown factors. 3) Technology cannot solve the problems of uncertainty related to innovation success. There may still be products at the developing stage that do not end up being a success.

Important categories in the social shaping of technology approach are relevant social groups, problems and solutions, technological frames and interpretative flexibility (Bijker, 1992, 1995). The actors / relevant social groups participate in a forming process by identifying problems and developing solutions interpreted through the groups' respective technological frame. Innovation is constituted by a technical frame that defines the specific technology/artefact as well as the actors. The technical frames include artefacts as examples, actors with their competences, methods, key problems, solution strategies, practice, test procedures, design methods etc. Technical frames both guide social shaping processes and are also the result of social shaping processes and transformations. Closure and stabilization can be perceived as two processes running simultaneously in a technological development. Closure related to the mechanisms that lead to a reduction of interpretative flexibility between relevant social groups as well as a reduction of the number of variants. Bijker introduces a redefinition of problems and rhetorical closures as central closure mechanisms to be used by actors in the actors' attempt to close the negotiations to their advantage or to reopen negotiations on a technology. Stabilisation relates to what is under construction and is thus a structural concept that focuses on what binds the constructed together and affect the actors as structures in the form of established networks, developed practices, etc. The technological frame ties closure and stabilisation processes together. It characterises the relationship between actors and artefacts and after stabilisation it will guide the actors.

Important aspects of open innovation are about the distribution of rights and obligations between actors in the innovation process, structures of innovation incentives and influence of innovation technologies. Different configurations of open innovation that are stabilised can be seen as part of technical frames that guides actors and structures different socio- technical settings in a specific way. In this perceptive, the different configurations will be created as part of the social shaping processes and the specific configuration will be inscribed in the technical frame that constitutes the innovation. In our case study, we take the specific configuration as a category of analysis, a focus that is absent in open innovation studies, and argue its relevance for understanding the dynamics of where and how different configurations of open innovation come into being.

3 METHODOLOGY

The case that we focused on is an open innovation project in the construction sector. The aim of the project was two-fold: to develop a concept for open innovation in construction and to develop daylight and energy solutions for the construction sector. The central actors in the innovation project in question were a major Danish architectural firm, a major building components manufacturer and the Danish Building Research Institute. The project developed three proposals for energy and daylight solutions for the construction industry that were developed to the level of ideas. The original purpose was to examine the possibilities for open innovation in the construction industry. Since only a limited number of studies with this focus have been reported, we chose an inductive, qualitative approach based on the in-depth analysis of the case. This approach provided the chance "to study life as it is lived and phenomena as they appear in real life" (Fog, 1992, p. 165). Our focus in this study was on learning how open innovation in the context of a building component manufacturer and a project-based company in the construction sector is developed and stabilised.

Two social factors played a significant role in the project's genesis. In 2006, the Danish

Building Regulations (BR06) introduced a new requirement to the energy performance of buildings based on energy frames, which represents a shift from descriptive regulation to performance-based regulation. The use of energy frames as the main requirements of new construction was a result of the EU Directive on Energy Performance of Buildings. With the shift from descriptive to performance-based regulation of energy requirements for buildings the need arose for new energy solutions in the construction industry. In 2007, the government launched a Programme for User-driven Innovation as part of a vision of Denmark as a leading innovative society. The purpose of the programme was to strengthen the development of new products, services, concepts and processes within public institutions and private companies on the basis of a better knowledge of customers and users. Based on the need for new energy solutions and the ability to obtain financing for an innovation project through the programme for user-driven innovation, the architectural firm formulated a project with the purpose of develop new daylight and energy solutions in the context of user-driven innovation. The project idea was to create a joint innovation process between a manufacturer of windows and the architectural firm where the architects as user of building components were the user. The architectural firm had long been working on the development of building membranes and wanted the project to develop new ideas for dealing with the desire to get daylight into buildings and to keep energy out of buildings, which is often perceived as conflicting requirements. The architectural firm recruited a large window manufacturer and the Danish Building Research Institute, which possessed the knowledge of daylight and energy issues in buildings, as key stakeholders in the project. The building component manufacturer’s motivation for joining the project was an interest in trying to work closely with an acknowledged architectural firm. The development project was planned as an iterative process where the previous phases would be a prerequisite for the subsequent phases. The project began with a definition of the purpose and scope. Then three mapping processes followed that aimed to create a knowledge base in their respective fields. Next followed a process of development of ideas, pre-prototypes and testing of selected ideas. Since focus of the analysis in this paper is on development and embedding of open innovation, the empirical work is limited to the pre-prototype phase and test, where the architectural firm and building component manufacturer worked together on developing three proposals for new energy and daylight solutions.

Engwall (2003) argues that projects are not lonely islands, but history-dependent and organisationally embedded. He emphasises structures and procedures employed in a project, and argues that they “have to be analysed in relation to previous and simultaneous courses of activity, to future plans, and to standard operating procedures, traditions, and norms of its organizational context” (Engwall, 2003, p.790). Thus case study therefore included a description of the companies. Following Engwalls argument an understanding of the involved companies are central to an analysis of a project, and a special focus centred on companies’ structuring of the project and the project's anchoring in the companies.

The project was characterised by the fact that both companies were development-oriented companies and that central knowledge actors within daylight and energy were involved. At the same time, the project participants had access to financial resources through financing from the programme for user-driven innovation. This was considered to have contributed to the project's ability to seek and develop knowledge. Conversely, these circumstances were assessed not to have had an impact on how open innovation structures were developed and stabilised in the three product development processes.

As with most qualitative studies, the study combined different collection methods, such as direct observation at meetings and workshops, project documentation as well as interviews. One or both authors have participated in joint workshops for the whole project team in the first half of the development project. In relation to the other phases from pre-prototyping and onwards in the second half of the development, participant observation was carried out in selected workshops. Throughout the project, documentation was produced in the form of reports, presentations, catalogues, analyses, current notes related to pre-prototype development, etc. This documentation was used as part of the basis for this analysis. In addition, information from the company websites was used etc. In the project's final phase, four qualitative research interviews were carried out with product manager and technical product manager from the building component manufacturer and with a construction architect, head of the development department, and an industrial designer from the architectural firm. The project management was divided between the building case architect and the industrial designer. Interviews were conducted on the basis of an interview guide. The interviews typically lasted 1 ½ to 2 hours. All interviews were recorded and subsequently transcribed.

4 EMPIRICAL ANALYSIS

4.1 The architectural firm

The architectural firm is a major Danish architectural firm operating in the global market with a focus on cultural buildings and domiciles. Competition projects are the core business and this is reflected in the firm’s internal organisation, which consists of a competition department, a design and planning department and a construction department. Each department represents different phases of the process, and the building project in this way moves through all three departments, which work almost independently. Architects’ needs in the design process related to the use of building components were identified in the daylight and energy project as the building components must be able to be manipulated to meet architect's needs first, to control the material second, to retain control over the development of the architecture. At the same time the necessary documentation had to be present, as it was a crucial factor for the introduction and use of new materials. The documentation was perceived as an important part of the argument for the use of new materials etc. to external partners. A few years ago, the firm established a small development department working with digital tools, new materials and green technologies in order to qualify the firm’s core business. The department’s work is network-based and has extensive contact with public and private companies, knowledge and research institutions etc. Work form varies between: 1) Research projects, where the department participates in interdisciplinary project teams, 2) Internal architectural projects, where the department qualifies work on a specific building case in relation technology, material inputs etc. or develop design tools, 3) External consultancy, which, among other things may be about to make architects’ needs visible in relation to a given development. The project in this analysis was formulated in this department.

4.2 The building component company

This company is the umbrella company for a number of activities within the manufacture of facade windows and consists of a number of independent companies. These companies develop, manufacture and market façade windows, facade systems, exterior doors, etc. They have production facilities in Denmark, Sweden, Norway, England and Poland. Among other tasks, the umbrella company supports the companies with product development and it has its own product development organisation with architects, designers and technicians as well as a large workshop with craftsmen etc. where they can quickly build physical models and make tests. The company uses the same product development concept as the one that is embedded in the organisation. Energy and indoor air quality, functionality, visual expression and price are used as four key points in the company’s product development process. The company emphasises that the process is not an iterative process where each parameter is tested and optimised, but rather a political philosophy in which the parameters figure as a whole. Generally, a product development process consists of 3-cycle processes where each cycle involves the development of prototypes and feedback from external stakeholders and users before a product is ready to be introduced on the market. The company gives priority to making pre-prototypes early in the product development phase. Physical models are perceived as physical manifestations of thoughts. The physical models and technical knowledge together with design knowledge are qualitative inputs to the process and are used to determine whether the principle is worth working on. The company's understanding is that design knowledge cannot stand alone, because it only represents creativity in one direction. The company's understanding is that the rapid switching between idea and materiality makes it easier quickly to recognise when something cannot be done or needs to change. The company's experience is that it becomes more difficult later in the development process to correct the error, because the budget is used in the development process itself. The company focuses on the entire value chain, also end–users, and uses all users from the different stages to qualify the product. The company sees the product as a process, because the product is constantly changing. The architect is perceived as a particularly important player, since the company expects to get feedback with greater design quality and longer perspectives from the architect than the end-user. But all users throughout the value chain are involved, based on the understanding that the products must satisfy the demands made by all the users. When the first prototype is developed, the company involves external architects with core competencies in that specific product or markets, which the product addresses. The company's experience of working with external architects, but also other users, is that the company itself has to know what it is the company want and that there has to be a physical model to show. The company's experience is that to clarify expectations is a key issue when users are involved. There is a tendency for users to take ownership of certain ideas, and this can lock both the process and themselves. It is necessary to constantly to keep "product" open. Often involved actors cannot recognise the finished product. When external actors are involved in product development, which means that the company has not taken out patents on the products, a cooperation agreement implies that the company has all the rights. The company uses demonstration projects to test their products in use by users.

4.3 Development of three energy and daylight solutions

The prototype phase took place in close cooperation between the building component manufacturer and the architectural firm. The cooperation is carried out both as video conferences and meetings. In the process of deepening and clarifying ideas, the companies used video conferences, while they held meetings during the process of developing real pre-prototypes. The reason why the companies used video conferences was that they were geographically far apart. The tasks between the companies was distributed so that the architectural firm was responsible for clarification of the basic geometry and functions, and the development department of the building component manufacturer was responsible for processing the pre-prototype, including support on technical development, dimensioning of subjects and development of real pre-prototypes.

4.4 The green screen

The concept of the green screen consisted of a "plant-shutter" placed on the outside of the building. Via a rail system, the plant-shutter can be placed next to or in front of the window. The screen consists of a frame in which plants can grow in a bowl and a rail system that can place the green screen in the desired position by means of a motor and bring water and fertiliser to the plants. The idea of the green-shutter was created in a brainstorming session, where the focus was on user needs for green plants and sun protection. The architectural firm was already involved in another development project about green cities and was interested in how to work with green facades. The building component manufacturer was recruited to the idea, but redefined the idea in the recruitment process from being a "green screen" to a question of brackets and a rail system as well as a potential opportunity for using the rail system to transport other materials than green plants. The company assessed that the market potential was greater if the expression could be varied. In the further process, the architectural firm was responsible for defining requirements for plant types, growth conditions, etc. and design of screen and rail system. From the previously mentioned project of green cities, the architectural firm recruited a plant nursery and an adviser to be responsible for collecting information on groups of plants, growing materials and irrigation systems. The building component manufacturer was responsible for producing a physical pre-prototype. Through the process, the concept was discussed between the architectural firm and the building component manufacturer in terms of desired characteristics - and requirements for the concept. Tests were carried out on plants' ability to block out the sun on the research institution's light lab, and to investigate whether the green screen was just as effective solar shading as other solar shadings on the market. In addition, a digital simulation was carried out in order to identify the requirements of the plants and to assess the view through the window. The concept of the green screen was constituted around a division of labour between the architectural firm, the building component manufacturer, the plant nursery and the consultant, where each actor contributed with different skills and had different interests in the concept. The development of the concept, the constitution of the relations between the actors and the created knowledge were co-produced in the same process.

4.5 The active window

The concept of the active window is about making the window an active part of the building and the user's interaction with the building. For the professional user the active window can be a user-interface, where the building's operation and condition can be read and adjusted. For the end-user the active window can act as user-interface between the end-user and the building's condition in relation to indoor climate, temperature etc. The idea is to make the active window into a platform on which various applications can be installed. This implies that the window must have embedded an electricity-feeding system and a data structure to which other components can be connected. The building component manufacturer had long worked on developing a window based on new materials. The manufacturer could see a long-term visionary perspective of the active window in relation to their on-going product development and the architectural firm and the building materials manufacturer decided to build on the manufacturer's on-going product development. Since the development of the active window was in this way was closely linked to the building component manufacturer's on-going product development the choice entailed that all the actors involved in the further process signed a declaration of rights in favour of the building component manufacturer. This was a normal procedure when the building component manufacturer involved external actors in key product development processes. Only one actor – a researcher - chose to stop on this background. The two companies decided that the aim of the process was a visualisation and description of the idea and not a physical pre-prototype. In order to explore the design quality of properties that could be attributed to the active window, a workshop was held for invited participants. The participants were selected on the basis of their specific specializations within user design, light design, climate control, etc. The architectural firm was responsible for organising the workshop. Based on the work discussion, the building component manufacturer and the architectural firm together drew up a presentation that could be tested on a group of the company's architects as a way to get the architects' assessment of the active window's potential on the market, how it might be used and expectations / requirements for the properties of the product.

4.6 The slideable window

Solar radiation through the window affects daylight in buildings and heat radiation. Heat radiation contributes to the heating of buildings, which in energy frame calculations is positive when there is a need for heating, and negative when it gives rise to a cooling need. The slideable window is a flexible design that allows the window to switch between two or more positions in the window opening. In winter, when there is a need for heating, the slideable window can be pushed so that it is flush with the facade, thus achieving maximum light and heat radiation. In summer, when there is often a need for cooling, the slideable window can be drawn back into in the window opening, so the window opening acts as solar and heat radiation reducers. The idea for the slideable window arose in connection with a brainstorming session. The window as example was reversed and rotated and the idea arose. The building component manufacturer’s interpretation of the idea was that it was interesting, but that it would be difficult to realise in practice. The team chose to pursue the idea and the aim was that the producer should make a pre-prototype that could be used for demonstration, but not to do a physical test. The solution was to develop a bracket that could shoot the window back and forth in the window opening. A control system that could move the window was developed. The potential of the idea was that the operating system should control the position of the slideable window based on real-time measurements of heating needs, i.e. the operating system should be able to measure the current situation in conjunction with the sun's position in the sky and time of day. The research institution made calculations that showed energy savings in the building's total energy consumption by shifting the window plane relative to the facade plane. In the calculations, it was necessary to manipulate with the simulation systems, as the systems were not designed to handle dynamic windows. The concept was further developed under the auspices of the project contract for the open innovation, i.e. all the involved partners could use the results. The common design process has not led to the development of a common technological frame for the slideable window as an example between the companies, since the building component manufacturer considers the solution as being too difficult to achieve in the short term. But energy-documentation have helped to push the boundaries of the existing technological frames where a representative from the building component manufacturer says "windows cannot simply be understood as static, but must also be understood as dynamic”, while an architect from the architectural company assessed that for them this is interesting in relation to thinking “dynamic facades”, as part of energy - and daylight solutions.

5 DISCUSSION

By using STS approach in the analysis, the three innovation processes shows different dynamics of how different configuration of open innovation comes into being. The green shutters are constituted around a concept where different companies have different interests in the idea and contribute with different types of knowledge and skills which together constitute the product idea. The shaping of the product idea and the network around the product idea is formed in one process, and is an example of how ‘the coupled process’ is established as an open innovation configuration. The active window is linked to one of the building component manufacturers’ existing product developing projects, which is an important part of the company’s strategic business strategy. In the process, the specific window is transformed to an intelligent window, which in a further development will link to technical companies as important alliance partners, if the concept has to be established as a product. In the innovation process, the architectural firm accepted to sign the rights declaration in favour of the building component manufacturer, because the process in itself contributed to learning about future options, learning about product development processes close to a building component manufacturer's core business and identification with the product. The shaping of the active window is an example of how 'the outside-in process' is established as an open innovation configuration. The slideable window is based on a window as a concept and not a specific window. The slideable window was not seen as a possible and feasible solution in the short term, but both companies had an interest in exploring the energy and daylight performance of the concept. The concept became to a large extent a fact through graphs and data produced in simulation systems, and what has stabilised is knowledge about the relationships between dynamic components and energy performance. There are no rights and obligations linked to the idea and the idea has been exhibited publicly – in this way, the idea is a free revealing innovation. The three examples suggest that specific configurations of open innovation can be difficult to plan when a specific configuration of open innovation is developed and stabilised together with a concrete innovation, which means that the innovation concept and the innovation as artefact, knowledge, methods etc. is the result of the same process.

Dodgson et al. (2006) found that innovation technology does not replace existing innovation practice, but can optimise it. They argue that innovation technology for example can result in that physical prototypes will be developed later, when there are fewer unknown factors. Development of physical prototypes at the building component manufacturer is an important part of the design process, where prototypes are perceived as physical manifestations of thoughts, which provides important qualitative input to the design process. In contrary to Dodgson et al. the findings illustrate that innovation technology does not postpone development of prototypes, but that they are mainly used to obtain additional knowledge about the concept's performance in this case energy and daylight performance, which may have an important role in shaping and stabilising the concept. The findings also illustrate that innovation technology in itself can act as both enabler and inhibiting factor in innovation processes. The experience of the simulation systems used was that on the one hand, they made it possible to develop data, but on the other hand, the researcher had to manipulate the simulation systems for testing of the slideable window because the systems are not developed to cope with dynamic components, but only static components.

6 CONCLUSIONS

Although the approach of open innovation has been productive, its conceptualisation of innovative structures and the dynamic of innovation structures does not allow for describing innovation processes where the distribution of rights and obligations between the architectural firm and the building component company, structures of innovation incentives and influence of innovation technologies are part of the innovation itself, which this analysis show. In this way the approach is not adequate to describe product development in project-based industries. To increase our understanding of current and future tendencies in an emerging sustainable construction industry - as well technical structures as organisational structures - more research on how building components are developed and stabilized within and between the companies are necessary.

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